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# Productivity Studies of Ultra High Density (UHD) Stitching Process

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***Abstract*—This paper focuses on Ultra High Density (UHD) stitching process of connectors, where the company relies on 100% manual inspection in UHD connectors. Based on historical data on production of UHD connectors, typically labour cost involved in inspection and testing is around 15% of the total manufacturing cost. This poses both challenges and opportunities for improvement in the bottleneck process, which is the inspection process. The female connectors quantity produced is on the average of 2000 parts/shift. It takes around 47 sec of visual inspection per connector and around 2.89 sec per piece for go-gauge inspection. Considering these factors, the objectives of the study was to understand the whole process in its entirety and then use this knowledge to re-organize the stages staring from the automatic stitching process. By using process improvement tools of time study, methods and process mapping, a process re-orientation and re-organization has been carried out. This resulted in not only reduction of time of inspection and testing of the connectors, but also the piece inspection process reduced from an average total time of 112.59 sec to 86.15 sec. Overall improvement was also increased from 56% to 79.5%.**

***Index Terms*—Process Mapping, Process Re-engineering, Ultra High Density.**

## I. INTRODUCTION

With emerging global competition and rising customer expectation, providing lowcost and high quality products is a winning mantra in the current business scenario.These high expectations can be met through low cost automation and by keeping lowoperational cost [1]. An automated visual inspection is one way for detecting all visual defects in a high volume manufacturing industry [2]. Colour image processing can be used for detecting the missing components or misaligned components. This can also be used for the visual inspection that results in high false call rate, which then leads to use background subtraction to identify defects. This feasibility decreases the setup costs by taking into account different types of data positioning, occlusions andtolerances [3]. New techniques have been proposed to reduce theinspection time using time-motion study.The paper illustrates the process ofinspection carried out in UHD connector [4]. Itwas found that by carrying out time and method study results in overall improvement of the process. Attribute agreement analysis can also be used to determine the inconsistencies of the defects in visual inspection of pass/fail decisions which can be identified and solve the main causes of poor inspection performance [5].The use of a priori knowledge about a scene to coordinate and control bi-level image segmentation, interpretation, and shape inspection of different objects in the scene. The approach is composed of two main steps. The first step consists of proper segmentation and labelling of individual regions in the image for subsequent ease in interpretation [6]. The common approaches to visual inspection, to consider the specification and analysis of

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dimensional tolerances and theirinfluence on the inspection task. Recent developments in automated visual inspection, is the expanded role of computer-aided design (CAD) data in many systems [7].

## II. Process Study and Mapping of UHD Stitching Process

Connectors are devices used for transmitting / connecting power and signals invarious fields like consumer goods, home appliances, communication devices,vehicles, aircraft, marinas etc. These connectors are essential for the functioning of much electronic equipment. A "connector" transmits electrical power and/or electronic signals betweentwo devices. It provides the vital link between electrical components with speed,efficiency and reliability. Connectors are normally produced in masswith many variants depending on the customer requirement. In fact, it is avolume game, where product cost and its margins will be low, but, volumes are high. Most of the time,the process is manual, where group of people have to sharethe activities and should perform the process to obtain a connector.

Connector basically consists of a plastic part that will act as insulator called‘Housing’; metal part which will connect or transmit power / signal called‘Terminals’. Housing and terminals are made in machines, but, assemblingthese two parts will be a core activity where more of human intervention is required, which is called as an ‘Assembly’. This is one of the important areas where an improvement was needed.Ultra High Density (UHD)connectors is a flexible and upgradeable connector system designed to fit 15 mm (0.6 inch) slot pitch applications and above. The UHD connector has an extremely high contact density combined with excellent high-speed signal performance. The UHD connectors are produced using a stitching process. The production line that is concentrated is the one that makes UHD slim connectors for various customers. The company relies on 100% manual inspection in UHD connectors.

*UHD stitching Process:*In this process, the Chiclets is inserted into the housing. This is a completely automated process and works with a high productivity rate. It takes 15 sec/connector.Continued research and closelymonitored trials have enabled to make this process an automated one.The stitching process at present managed by 2 operators and the chiclets feeding,lubrication, bridge-cutting (punch out of mould), carrier separation, pre-insertion, toplocking,side-locking, laser date coding all in one automated process. The production line for UHD connectors is optimizedby drastically reducing inspection and testing costs in the long run.

The following are the major processes involved in the production process of UHD connectors. The flow process for UHD Connector is shown in the Fig. 1 below.

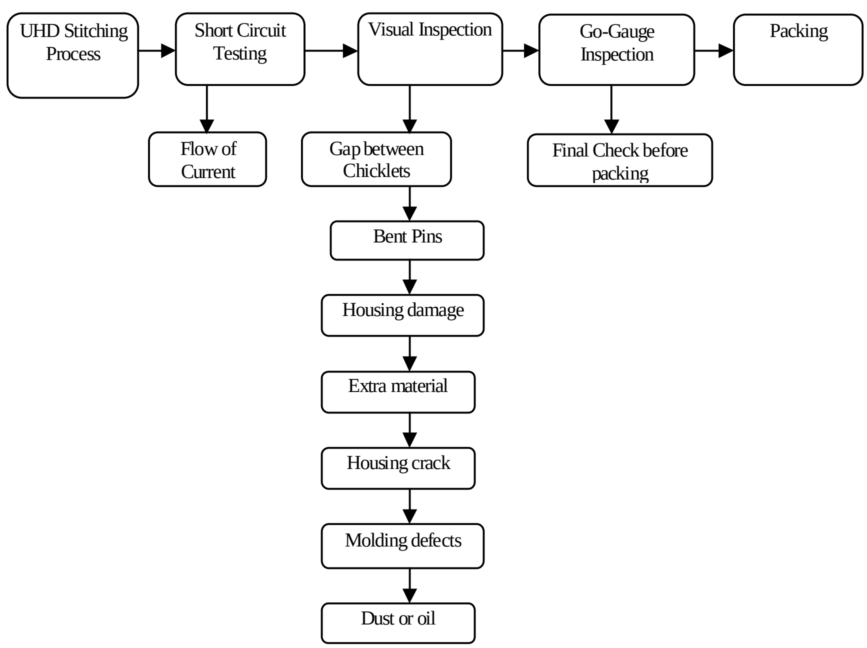


Fig. 1:Existing UHD stitching process

i. *Short Circuit Testing:* A short circuit (sometimes abbreviated as s/c) is an electrical circuit that allows a current to travel along an intended path, often where essentially no or a very low electrical impedance is encountered. The electrical opposite of a short circuit is an open circuit, which is an infinite resistance between two nodes.Short circuit testing is done as the next process. The connectors are loaded into a tray that can fit 121 female connectors. When this tray is full, it is transported for short-circuit testing. Only 1 operator is available per batch of 121 connectors.
ii. *Visual Inspection:* Visual inspection is a process whereby an operator with the help of his/her eyes, with or without the use of visual aid, inspects a component or product for defects, flaws or abnormalities.
iii. *Go-Gauge Inspection:* A Go-No Go gauge refers to an inspection tool used to check a work piece against its allowed tolerances. Its name derives from its use: the gauge has two tests; the check involves the work piece having to pass one test (Go) and fail the other (No Go).
iv. *Packing:* The packing is done in polyurethane trays; it is the final step that is undertaken in the facility before it is shipped out of the facility to the customers. The operator first puts each individual female connector into jackets provided on the tray. The tray is then covered with one sheet of clear plastic for every row on the tray. For the female connector, each tray consists of 50 pieces. One box that is shipped to the customer consists of 5 such trays. Therefore, one box/carton consists of 250 female connectors. The box is then sealed and shipped.

## III. METHODOLOGY OF STUDY

Based on historical data for this type of production, it has been observed that typically labour cost involved in inspection and testing represents as much as 15% of the total manufacturing cost. Since recently the company has created an automated UHD stitching machine for the assembly of the UHD connectors observed that the processes after the assembly process was noticed as being thebottle necks. To analyse this, following methodology has been adopted for study:

### *A. Data Collection*

The following data collection for numerical computation was done in the following processes:

- *Visual Inspection:* Visual inspection is a process wherebyan operator with the help of his/her eyes, with or without the use of visual aid, inspects a component or product for defects, flaws or abnormalities. Table 1 show the time study carried out to know details of each connector being inspected. Table 1 shows the data gathered by observing 3 inspectors inspecting 20components at a stretch. The time is then averaged to obtain the time taken to inspect one of such component. This process was repeated 10 times for each of the threeinspectors. The readings were observed for the same inspector, once inthe morning and once in the afternoon. The subtle increase in time taken to inspect inthe afternoon is clearly noticed. The overall time taken per piece was 47.78 sec/piece.

TABLE I: TIME STUDY FOR VISUAL INSPECTION

| FEMALE PART VISUAL INSPECTION (Average of 20 pieces inspected in seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Days | Operator | Morning | Afternoon | Operator | Morning | Afternoon | Operator | Morning | Afternoon |
| 1 | 1 | 33.2 | 37.2 | 2 | 53.9 | 59.2 | 3 | 43.1 | 47.7 |
| 2 | 1 | 34.4 | 35.7 | 2 | 57.3 | 55 | 3 | 45.1 | 48.1 |
| 3 | 1 | 38.2 | 34.4 | 2 | 53.1 | 56.9 | 3 | 45.8 | 46.2 |
| 4 | 1 | 31.9 | 40.6 | 2 | 58.3 | 56.4 | 3 | 43.1 | 45.5 |
| 5 | 1 | 38.6 | 36.2 | 2 | 61.2 | 61.2 | 3 | 51.3 | 49.3 |
| 6 | 1 | 33.1 | 41.1 | 2 | 52.4 | 59.4 | 3 | 47.2 | 53.8 |
| 7 | 1 | 37.7 | 43.2 | 2 | 58.1 | 63.1 | 3 | 48.8 | 50.3 |
| 8 | 1 | 40.1 | 41.7 | 2 | 55.5 | 55.9 | 3 | 49.1 | 53.1 |
| 9 | 1 | 43.5 | 36.6 | 2 | 55.2 | 57.4 | 3 | 45.3 | 48.1 |
| 10 | 1 | 34 | 43.5 | 2 | 60.3 | 60.1 | 3 | 49 | 52.1 |
| | Time taken for 400 pieces | | 754.9s | | | 1149.9s | | | 962s |
| | Avg time taken/ piece | | 37.75s/piece | Avg time taken/piece | | 57.5 /piece | Avg time taken/ iece | | 48.1 s/piece |
| Overall time taken per piece | | | | | | | | | 47.78s/piece |

- *Go-Gauge Inspection:* To gauge how long an operator requires to do a go-gauge for one component, the time for 100 components was obtained by observing first. It was done for a 2 week period, in which time for 2000 component's go-gauge testing was obtained as shown in Table 2. The operator first waits for the

full tray (121 components) to be acquired to his station. After which he/she picks up one component at a time from the tray and tests it using the go-gauge tester resting on the surface of the workstation.From the Table 3.2, the go gauge total inspection in the morning for 2000pieces was found to be 5722sec and the average for 100pieces was found to be 286.1sec. Similarly, in the evening, for 2000pieces, the total inspection time was 5817sec and theaverage for 100pieces was found to be 290.8sec.

TABLE II: EXISTING GO-GAUGE TIME STUDY

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Testing. 2 week 100 components in sec | Morning | 280 | 290 | 289 | 279 | 300 | 298 | 269 | 277 | 278 | 298 |
| | | 294 | 276 | 291 | 287 | 268 | 298 | 287 | 297 | 278 | 288 |
| | Total Morning inspection for 2000 pieces: 5722 s<br>Average Morning/100 pieces: 286.1 s | | | | | | | | | | |
| | Afternoon | 285 | 297 | 299 | 269 | 296 | 305 | 279 | 289 | 283 | 285 |
| | | 280 | 291 | 295 | 290 | 299 | 302 | 312 | 296 | 288 | 277 |
| | Total Evening inspection for 2000 pieces: 5817 s<br>Average Evening/100 pieced: 290.8 s | | | | | | | | | | |

*B.Data Analysis*

After consolidation of the data of inspection process, a brainstorming session was organised among the team members. The output of the brainstorming session revealed that some of the process in inspection to be re-visited and swapped for effectiveness and reduction in inspection time.The following Fig. 2 shows the revised UHD Stitching process.

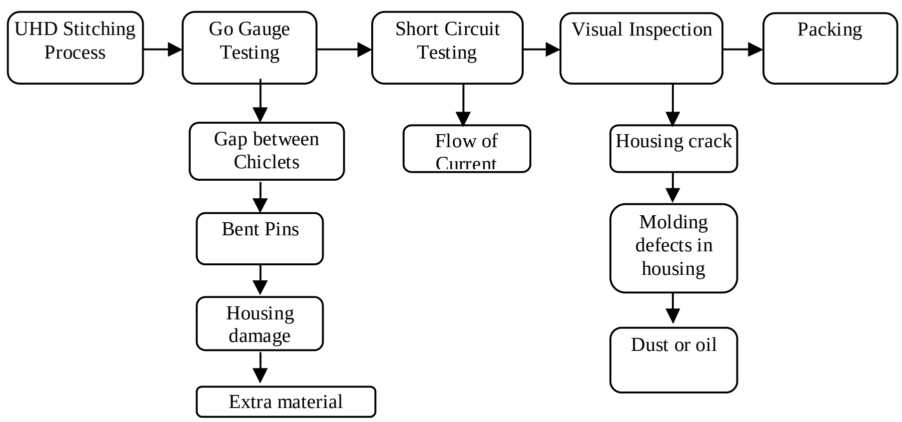


Fig. 2: Proposed UHD Stitching Process

The UHD Stitching processwas carried out, as earlier. There was no change in thisprocedure, as it is an automated process. The changes in the go gauge insection were done in the revised process using time study again. The UHD stitcher produces a batch of 3 connectors. Each connector takes 15 sec to bemade and therefore a batch of 3 connectors takes 45 sec. The operator collects these connectors and was idle for until next batch of 3 connectorsare produced (for 45 sec). So assoon as a batch of 3 UHD connectors come out of the stitching machine, the operatorcollects the parts from the stitching process and test them using a go-gauge.The proposed method eliminated the idle time that previously existed in the system and alsoeliminated time for movement and collections of the parts. The Table 3 below shows the Go gauge testing times for proposed method.

Although the time for go-gauge testing is not dramatically reduced as shown in Table 3.3, it doeseliminate the idle time during WIP of the connectors being produced in the UHDstitcher. More importantly, because the go-gauge testing is re-oriented to happenbefore the visual inspection, the time for visual inspection is cut by half. The average morning inspection time for 100 pieceswas found to be 285.2 sec and average evening inspection time for 100 pieces was found to be 289.8 sec. The short circuit testing was carried out, as it was earlier. There was no change in this procedure.

Table 4 shows the performance rating was done for workers doing the fully manual visual inspection process. The performance rating was done solelybased on speed and paceof the workers.

TABLE III: PROPOSED GO-GAUGE TIME STUDY

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Testing. 2 week 100 components in sec | Morning | 280 | 290 | 289 | 279 | 310 | 298 | 269 | 277 | 278 | 298 |
| | | 294 | 280 | 296 | 287 | 268 | 298 | 287 | 297 | 278 | 288 |
| | Total Morning inspection for 2000 pieces: 5704 s<br>Average Morning/100 pieces: 285.2 s | | | | | | | | | | |
| | Afternoon | 290 | 297 | 299 | 269 | 296 | 310 | 279 | 289 | 289 | 290 |
| | | 280 | 291 | 295 | 290 | 299 | 302 | 312 | 296 | 288 | 277 |
| | Total Evening inspection for 2000 pieces: 5796 s<br>Average Evening/100 pieced: 289.8 s | | | | | | | | | | |

The analysis was done for 20 inspections. Based on observations and averages, and company's own standard for inspection, the conclusion was that, for a female connector, the standard rating that is considered to be 100% is 48 seconds/piece. As depicted in the table 3.3, the Inspector 1 takes an average of 37.75 sec/piece and therefore his performance rating is more than 100.Using the formula 1+ {(|Standard Time– Actual Time|)/Actual Time} for when actual time is smaller than standard time, then, performance rating is 127.2.Inspector 2 takes an average of 57.5 sec/piece and his performance rating is 83.34 and is less than 100. Inspector 3 takes an average of 48.1 sec/piece and his performance rating is 99.7 which isclose to 100. As the go-gauge inspection happens earlier and it eliminates 3 defect parameters, there was a drastic change in the visual inspection time. Earlier the inspector would look for 6 defect parameters to be inspected for, in the process. In the proposed system, the person can look for only 3 defect parameters as the other three were eliminated in the go-gauge inspection. This reduces the time for inspection.

TABLE IV: PERFORMANCE RATING OF INSPECTORS

| Inspector 1 | | Inspector 2 | | Inspector 3 | |
|---|---|---|---|---|---|
| Morning | Afternoon | Morning | Afternoon | Morning | Afternoon |
| 33.2 | 37.2 | 53.9 | 59.2 | 43.1 | 47.7 |
| 34.4 | 35.7 | 57.3 | 55 | 45.1 | 48.1 |
| 38.2 | 34.4 | 53.1 | 56.9 | 45.8 | 46.2 |
| 31.9 | 40.6 | 58.3 | 56.4 | 43.1 | 45.5 |
| 38.6 | 36.2 | 61.2 | 61.2 | 51.3 | 49.3 |
| 33.1 | 41.1 | 52.4 | 59.4 | 47.2 | 53.8 |
| 37.7 | 43.2 | 58.1 | 63.1 | 48.8 | 50.3 |
| 40.1 | 41.7 | 55.5 | 55.9 | 49.1 | 53.1 |
| 43.5 | 36.6 | 55.2 | 57.4 | 45.3 | 48.1 |
| 34 | 43.5 | 60.3 | 60.1 | 49 | 52.1 |
| Average=37.75s/piece<br>Performance rating = 127.2 | | Average=57.5s/piece<br>Performance rating = 83.34 | | Average=48.1s/piece<br>Performance rating = 99.7 | |

The table 5 shows the results of the time study for proposed visual inspection, where the overall time taken/piece is24.25s/piece. This shows an improvement 49.24% in the visual inspection process. The Packagingprocess was carried out, as earlier.

TABLE V: TIME STUDY FOR PROPOSED VISUAL INSPECTION

| FEMALE PART VISUAL INSPECTION (average of 20 pieces inspected in seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Days | Operator | Morning | Afternoon | Operator | Morning | Afternoon | Operator | Morning | Afternoon |
| 1 | 1 | 22 | 21 | 2 | 28 | 28 | 3 | 25 | 23 |
| 2 | 1 | 21 | 18 | 2 | 29 | 29 | 3 | 26 | 21 |
| 3 | 1 | 24 | 19 | 2 | 25 | 24 | 3 | 24 | 26 |
| 4 | 1 | 20 | 20 | 2 | 27 | 28 | 3 | 27 | 25 |
| 5 | 1 | 18 | 21 | 2 | 24 | 27 | 3 | 28 | 27 |
| 6 | 1 | 19 | 25 | 2 | 28 | 30 | 3 | 25 | 22 |
| 7 | 1 | 17 | 22 | 2 | 27 | 25 | 3 | 24 | 28 |
| 8 | 1 | 22 | 22 | 2 | 26 | 29 | 3 | 25 | 27 |
| 9 | 1 | 21 | 27 | 2 | 24 | 28 | 3 | 26 | 21 |
| 10 | 1 | 20 | 17 | 2 | 26 | 34 | 3 | 24 | 19 |
| Time taken for 400 pieces -Total | | | 416s | Total | | 546s | Total | | 493s |
| Avg time taken/ piece | | | 20.8s/piece | Avg time taken/ piece | | 27.5 s/piece | Avg time taken/ piece | | 24.65 s/piece |
| Overall time taken per piece | | | | | | | | | 24.25s/piece |

## IV. SUMMARY OF RESULTS

The analysis of the study revealed that the proposed system of inspection would yield better results and enhance productivity. The inspection process included the microscopic visual inspection; short-circuit testing and go-gauge inspection. The visual inspection was observed to take an average of 46.59 s per connector in the morning (this average was an average of 3 different inspectors). It was observed that this inspection time increased to an average of 48.96 per piece in the afternoon. The average inspection time was observed to be 47.78/piece. The go gauge testing was done for the pins on top of the chiclets. On an average, go gauge testing time for female connectors was found to be 2.89 s/piece. With the help of time study, method study using process mapping, a process re-orientation and re-organization was done. This re-orientation resulted in a reduction in time for inspection and testing of the connectors.

## V. CONCLUSION

The Fig 3 shows comparison of results of present and proposed method of inspection process which reduced from an average total time of 112.59sec to 86.15sec.

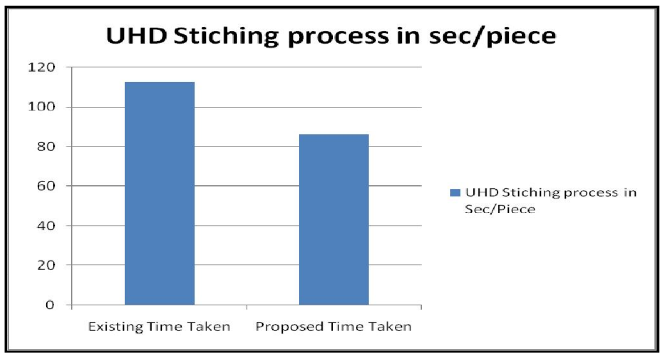


Fig. 3: Comparison of results

Although the go-gauge inspection did not reduce in time, the re-orientation of the go-gauge testing before the visual inspection, gave the overall improvement which increased from 56% to 79.5%.

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